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SPECIFICATION FOR CADMIUM COPPER CONDUCTORS FOR OVERHEAD RAILWAY TRACTION

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MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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SPECIFICATION FOR CADMIUM COPPER CONDUCTORS FOR OVERHEAD RAILWAY TRACTION

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TO

IS:3402-1965 SPECIFICATION FOR CADMIUM COPPER CONDUCTORS FOR OVERHEAD RAILWAY TRACTION

Addendum

(*Page 7, clause 5.1*) - Add the following new clause after 5.1 and renumber the existing clause '5.2' as '5.3':

'5.2 The exact manufacturing lengths for the conductor shall be as agreed to between the purchaser and the manufacturer. The lengths may vary between 500 and 3 200 metres.'

(ETDC 60)

Reprography Unit, ISI, New Delhi, India

Indian Standard

SPECIFICATION FOR CADMIUM COPPER CONDUCTORS FOR OVERHEAD RAILWAY TRACTION

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 6 September 1965, after the draft finalized by the Conductors and Cables Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 In preparing this standard, assistance has been derived from the following standards:

B.S. 2755 : 1956 Specification for copper and cadmium copper stranded conductors for overhead electric traction systems. British Standards Institution.

B.S. 2873 : 1963 Specification for schedule of copper and copper alloys wire. British Standards Institution.

0.3 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960[*]. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This specification covers the requirements of cadmium copper conductor to be used for overhead railway traction.

2. TERMINOLOGY

2.1 For the purpose of this standard, the definitions given in IS : 1591-1960[†] shall apply.

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[*] Rules for rounding off numerical values (*revised*).

[†] Glossary of terms for electrical cables and conductors. [Superseded by IS : 1885

3. CONDUCTOR

3.1 Material — The conductor shall consist of copper alloyed with cadmium; presence of a de-oxidizing agent in the alloy shall be permissible.

3.2 Resistivity — At a temperature of 20°C the maximum value of the resistivity of the hard-drawn cadmium copper permitted by this standard is 0·021 769 ohm. mm^2/m.

NOTE — This resistivity corresponds to a conductivity of 79·2 percent of that adopted by the International Electrotechnical Commission for 'standard annealed copper'.

3.3 Density — At a temperature of 20°C the density of hard-drawn cadmium copper has been taken as 8·945 g/cm^3.

3.4 Coefficient of Linear Expansion — At a temperature of 20°C the coefficient of linear expansion of hard-drawn cadmium copper has been taken as 0·000 017 per degree Celsius. This coefficient may be used over a temperature range from 0° to 150°C.

3.5 Constant-Mass Temperature Coefficient of Resistance — At a temperature of 20°C the coefficient of variation of the resistance with temperature of hard-drawn cadmium copper, measured between two potential points rigidly fixed to the wire, the metal being allowed to expand freely, has been taken as 0·003 1 per degree Celsius.

3.6 Freedom from Defects — The wire shall be clean, smooth and free from harmful defects.

3.7 Standard Resistance, Weight and Size of Solid Conductor — After drawing, the wire shall have the diameter, weight and the resistance given in Table 1.

3.8 Standard Resistance, Weight and Size of Stranded Conductor — The size, weight and resistance of stranded circular conductor shall be as given in Table 2 (*see also* Appendix A).

3.9 Tolerances on the Standard Diameter and Resistance of Conductors — A tolerance of ±2 percent shall be permitted on the standard weight of solid wires and stranded conductors.

3.9.1 The diameter of the wire shall fall within the appropriate maximum and minimum values given in Table 1 which are the maximum and minimum mean diameters permissible in order that the specified tolerance of 2 percent on the weight shall not be exceeded.

3.9.2 The cross-section of any wire shall not depart from circularity by more than an amount corresponding to a tolerance of 2 percent on the standard diameter.

TABLE 1 SOLID CIRCULAR CADMIUM-COPPER WIRES

(*Clauses* 3.7, 3.9.1, 3.9.3, 3.10, 6.2.2 *and* 6.3)

DIAMETER			CALCULATED AREA OF CADMIUM COPPER	NOMINAL EQUIVALENT AREA OF HARD-DRAWN COPPER	WEIGHT PER km			RESISTANCE PER km AT 20°C CORRECTED TO STANDARD WEIGHT		MINIMUM BREAKING LOAD CALCULATED ON MINIMUM DIAMETER	MINIMUM BREAKING LOAD CALCULATED ON STANDARD DIAMETER	MINIMUM TENSILE STRENGTH
Standard	Maximum	Minimum			Standard	Maximum	Minimum	Standard	Maximum			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
mm	mm	mm	mm²	mm²	kg	kg	kg	ohms	ohms	kg	kg	kg/mm²
2·10	2·12	2·08	3·464	2·826	30·93	31·60	30·36	6·285	6·348	225	229	66·14

NOTE 1 — The values specified in col 11 are the minima with which the wires shall comply before stranding (*see* **6.2**).

NOTE 2 — The values specified in col 12 are the bases from which approximate breaking load of the stranded conductors listed in Table 2 have been calculated.

TABLE 2 STANDARD CADMIUM-COPPER STRANDED CONDUCTORS

(*Clauses* 3.8 *and* 6.3)

NOMINAL EQUIVALENT AREA OF HARD-DRAWN COPPER	NO. OF STRANDS AND DIAMETER OF WIRE	APPROXIMATE OVERALL DIAMETER	WEIGHT PER km			RESISTANCE PER km AT 20°C CORRECTED TO STANDARD WEIGHT		APPROXIMATE BREAKING LOAD OF CONDUCTOR	CALCULATED AREA OF CADMIUM COPPER
			Standard	Maximum	Minimum	Standard	Maximum		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
mm²	mm	mm	kg	kg	kg	ohms	ohms	kg	mm²
53	19/2·10	10·5	597·3	609·2	585·3	0·336	0·339	3 920	64·84
102	37/2·10	14·7	1 169·2	1 192·6	1 145·8	0·173	0·175	7 650	125·60

3.9.3 The resistance of the wire when measured and corrected as described in **6.3** shall not exceed the appropriate maximum value given in Table 1.

3.10 Mechanical Properties — The mechanical properties of the wire shall be such that the tensile strength when tested in accordance with **6.2.2** shall be not less than the appropriate value given in Table 1.

3.10.1 The wire shall comply with the wrapping test as given in **6.2.1**.

3.11 Joints in Wire Before Stranding — The wires shall be drawn in continuous lengths without joints except those made in the original rods before drawing.

3.12 Joints in Stranded Conductors — A joint in any wire in a stranded conductor shall be permitted provided that no two joints (other than those in wire before stranding permitted in **3.11**) occur at points in the stranded conductor nearer together than 15 metres. Joints should be hard soldered or welded.

3.12.1 Any soldered joint in a stranded conductor as permitted in **3.12** shall have a breaking strength not less than 22 kg/mm^2.

4. STRANDING

4.1 The wire used in the construction of a stranded conductor shall before stranding satisfy all the requirements of this standard for solid wires.

4.2 The lay ratio of different layers shall be within the limits specified in Table 3.

TABLE 3 LAY RATIO

NUMBER OF WIRES	LAYER AND NUMBER OF WIRES					
	First Layer		Second Layer		Third Layer	
	Max	*Min*	*Max*	*Min*	*Max*	*Min*
(1)	(2)	(3)	(4)	(5)	(6)	(7)
19	25	20	17·5	15	—	—
37	25	20	17·5	15	15	12·5

4.3 In all constructions the successive layers shall have opposite direction of the lay, the outermost layer being right-handed.

5. PACKING AND MARKING

5.1 The cadmium copper stranded conductors shall be delivered to the purchaser properly wound on drums (*see also* IS : 1778-1961*). The spindle plates of the drums shall have a square hole 105 mm × 105 mm to permit the passage of a square axle of maximum size 100 mm × 100 mm. The use of spindle plates with a hole of any other shape or size shall be subject to agreement between the purchaser and the manufacturer. A drum shall carry only one continuous length of stranded conductor.

5.2 The labelling on the drum shall be as follows:

a) The manufacturers' brand or mark,
b) Size of the conductor,
c) The actual length of the wire on the drum,
d) Weight of drum (nett and gross), and
e) Drum number.

6. TESTS

6.1 Test Samples — The mechanical tests shall be made on single wires only. In the case of stranded conductor, the samples shall be taken from the wire before stranding except as provided in **6.2.2**.

6.2 Mechanical Tests

6.2.1 *Wrapping Test* — The wire shall not break when tested in the following manner.

6.2.1.1 The wire shall be wrapped round a wire of its own diameter to form a close helix of 8 turns. Six turns shall then be unwrapped and then closely re-wrapped in the same direction as the first wrapping.

6.2.2 *Tensile Test* — This test shall apply to wires of all diameters and to the component wires of the stranded conductors, the test on the latter being made, whenever practicable, before stranding. The tensile strength of a wire before stranding, when tested in the manner as explained below, shall be not less than the appropriate value given in Table 1. If it is not possible to test the component wires of the stranded conductor before stranding, the test may be made on wires taken from the conductor. In such cases the tensile strength of any of the wires shall be not less than 92·5 percent of the value given in the Table 1 and the average tensile strength of all the wires in a stranded conductor shall be not less than 94 percent of the value specified in Table 1.

6.2.2.1 The load shall be applied gradually and the rate of separation of the jaws of the testing machine shall not be greater than 10 cm per minute, and shall be so adjusted that the total time of the testing from the moment of the application of the load till fracture is between 15 and 60 seconds.

---

*Specification for reels and drums for bare wire.

NOTE — The strength of a stranded conductor in terms of the sum of the strengths of the individual component wires may be assumed to be not less than as follows:

Number of Wires in Strand	*Percentage Strength based on the Strength of the Wires when taken from the Stranded Conductor and Tested*	*Percentage Strength based on the Strength of the Component Wires before Stranding*
(1)	(2)	(3)
19	93	90
37	93	90

6.3 Resistance Test — The electrical resistance per kilometre of the test sample multiplied by:

$$\frac{W}{K} \times C$$

shall not exceed an appropriate maximum value given in Tables 1 and 2,

where

K = standard weight per km,

W = weight per km of test sample, and

C = multiplier constant for correction to 20°C. The multiplier constant shall be in accordance with Table 4.

The measurement of resistance shall be carried out to an accuracy of at least one part in thousand.

TABLE 4 MULTIPLIER CONSTANTS FOR CONVERSION OF ELECTRICAL RESISTANCE TO 20°C

(*Clause* 6.3)

Constants for converting resistances at various temperatures of hard-drawn cadmium copper to the standard temperature of 20°C, and reciprocals of the constants for converting resistances at 20°C to other temperatures.

TEMPERATURE	MULTIPLIER CONSTANT	RECIPROCAL OF CONSTANT	TEMPERATURE	MULTIPLIER CONSTANT	RECIPROCAL OF CONSTANT
(1)	(2)	(3)	(1)	(2)	(3)
°C			°C		
5	1·049	0·954	7	1·042	0·960
5·5	1·047	0·955	7·5	1·040	0·961
6	1·045	0·957	8	1·039	0·963
6·5	1·044	0·958	8·5	1·037	0·964

(*Continued*)

TABLE 4 MULTIPLIER CONSTANTS FOR CONVERSION OF ELECTRICAL RESISTANCE TO 20°C — *Contd*

Temperature (1) °C	Multiplier Constant (2)	Reciprocal of Constant (3)
9	1·035	0·966
9·5	1·033	0·968
10	1·032	0·969
10·5	1·030	0·971
11	1·029	0·972
11·5	1·027	0·974
12	1·025	0·975
12·5	1·024	0·977
13	1·022	0·978
13·5	1·021	0·980
14	1·019	0·981
14·5	1·017	0·983
15	1·016	0·985
15·5	1·014	0·986
16	1·013	0·988
16·5	1·011	0·989
17	1·009	0·991
17·5	1·008	0·992
18	1·006	0·994
18·5	1·005	0·995
19	1·003	0·997
19·5	1·002	0·999
20	1·000	1·000
20·5	0·998	1·002
21	0·997	1·003
21·5	0·995	1·005
22	0·994	1·006
22·5	0·992	1·008
23	0·991	1·009
23·5	0·989	1·011
24	0·988	1·012
24·5	0·986	1·014
25	0·985	1·016
25·5	0·983	1·017
26	0·982	1·019
26·5	0·980	1·020
27	0·979	1·022
27·5	0·977	1·023
28	0·976	1·025
28·5	0·974	1·026
29	0·973	1·028
29·5	0·971	1·030
30	0·970	1·031
30·5	0·968 7	1·032 3
31	0·967 0	1·034 1
31·5	0·965 5	1·035 7
32	0·964 1	1·037 2
32·5	0·962 6	1·038 8
33	0·961 3	1·040 3
33·5	0·959 8	1·041 9
34	0·958 4	1·043 4
34·5	0·956 9	1·045 0
35	0·955 6	1·046 5
35·5	0·954 1	1·048 1
36	0·952 7	1·049 6
36·5	0·951 3	1·051 2
37	0·949 9	1·052 7
37·5	0·948 5	1·054 3
38	0·947 1	1·055 8
38·5	0·945 7	1·057 4
39	0·944 4	1·058 9
39·5	0·943 0	1·060 5
40	0·941 6	1·062 0
40·5	0·940 2	1·063 6
41	0·938 9	1·065 1
41·5	0·937 5	1·066 7
42	0·936 2	1·068 2
42·5	0·934 8	1·069 8
43	0·933 4	1·071 3
43·5	0·932 1	1·072 9
44	0·930 8	1·074 4
44·5	0·929 4	1·076 0
45	0·928 1	1·077 5

NOTE 1 — Given the resistance of a wire at *T*°, the resistance at 20°C is found by multiplying the resistance at *T*° by the constant for *T*°, given in col 2. Conversely, given the resistance at 20°C, the corresponding resistance at *T*° is found by multiplying the resistance at 20°C by the reciprocal for *T*°, given in col 3.

NOTE 2 — The temperature resistance coefficients of a large number of samples of cadmium copper complying with the requirements of this standard have been found to vary between 0·003 1 and 0·003 5 per degree Celsius. There is some evidence to suggest that the coefficients of copper alloys in general are directly proportional to their conductivities. In this standard the value of 0·003 1 has been adopted as it lies within the observed range and also complies with the above theory if it be assumed that all cadmium copper has the maximum resistivity permitted (*see* **3.2**).

7. CRITERION OF APPROVAL

7.1 If a sample selected for testing fails to comply with any one or more of the tests laid down in the specification, two further tests shall be made on samples from the same length of stranded conductors in the same manner. If either of the sample fails in the repeated test, the length of the wire represented shall be rejected.

APPENDIX A

(*Clause* 3.8)

NOTES ON THE CALCULATION OF TABLE 2

A-1. DATA CONCERNING STRANDED CONDUCTORS

A-1.0 Table 2 has been drawn up on the following basis.

A-1.1 When straightened out, each wire in any particular layer of the standard conductor, except the central wire, is assumed to be longer than the stranded conductor by an amount depending on the mean lay ratio (*see* **4.2**) of that layer (*see* Table 5).

TABLE 5 INCREASE IN LENGTH DUE TO STRANDING

	FIRST LAYER	SECOND LAYER	THIRD LAYER
Mean lay ratio	22·5	16·25	13·75
Percentage increase in length (calculated)	0·970	1·85	2·57

A-1.2 The weight of each wire in any particular layer of a stranded conductor, except the central wire, will be greater than that of an equal length of straight wire by an amount depending on the mean lay ratio of that layer (*see* **A-1.1**).

In Table 2, the areas, weights and resistances of the strands have been calculated by multiplying the corresponding values for one of the single wires of which the conductor is composed by the constants set out in Table 6.

TABLE 6 MULTIPLIER CONSTANTS FOR STRANDED CONDUCTORS

NUMBER OF WIRES STRANDED	CONSTANT		
	Area	Weight	Resistance
(1)	(2)	(3)	(4)
7	6·942	7·058	0·144 0
19	18·72	19·28	0·053 4
37	36·26	37·74	0·027 6

A-1.3 Calculated Area — This term denotes the area of a solid cadmium copper rod which would have the same resistance as the stranded conductor, assuming the same conductivity. This area, therefore, takes into account the assumed increase of resistance of each wire except the central wire (*see* **A-1.1**) and can be determined by multiplying the area of any one wire by a constant as set out in Table 6 which is the reciprocal of the constant for calculating resistance.

A-1.4 Nominal Copper Area — This term denotes in round figures the area of a solid hard-drawn copper rod of resistance approximately equal to that of the cadmium copper stranded conductor.

A-1.5 Table 6 has been calculated for, and is only applicable to, the standard constructions of stranded conductors specified in this standard.

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

QUANTITY	UNIT	SYMBOL
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

QUANTITY	UNIT	SYMBOL
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

QUANTITY	UNIT	SYMBOL	DEFINITION
Force	newton	N	1 N = 1 kg.m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2

INDIAN STANDARDS INSTITUTION

Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002

Telephones : 26 60 21, 27 01 31 **Telegrams : Manaksanstha**

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